Transmutation Physics

Eric Pitcher
Los Alamos National Laboratory

AFC Quarterly Review
24 January 2003

Areas of research in transmutation physics

- MCNPX Code Development
  - Updated to MCNP4C
  - “Mix and match” implemented
- Data Development
  - Actinides added to LA150 library
  - New Pb-208 evaluation
  - Minor actinide evaluations
- Experiments
  - Neutron leakage from thick LBE targets
  - Gas production cross section measurements
  - Actinide capture and fission cross section measurements
  - Minor actinide temperature coefficients measurements

Recent MCNPX Developments

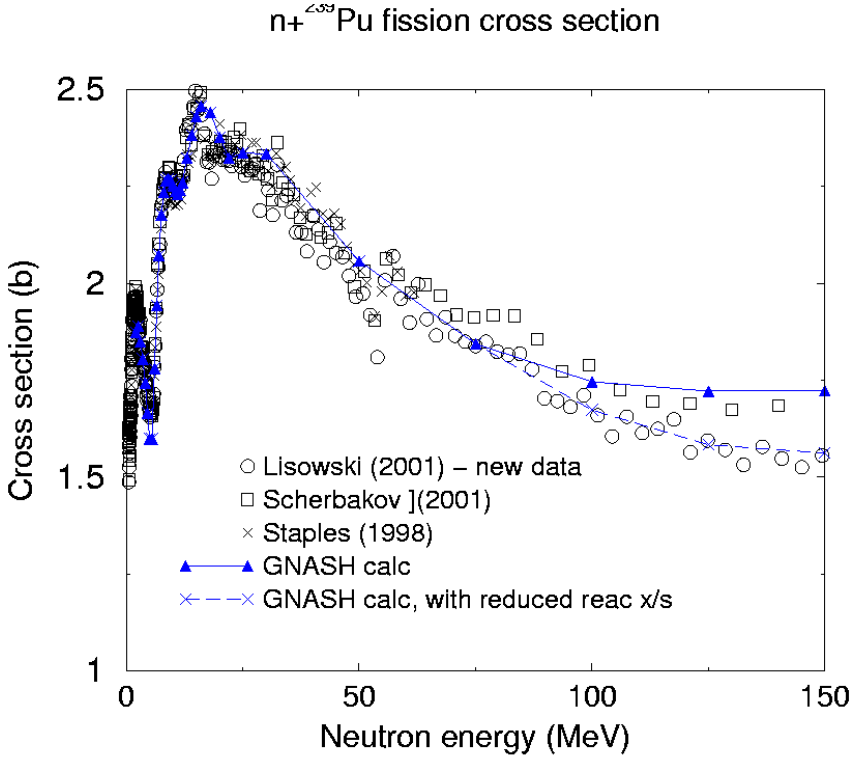
- MCNPX updated to MCNP version 4C
  - Time-dependent delayed neutrons
  - Simplified user input and superior graphical output
- Improved physics including spontaneous fission, light ion recoil, low-energy charged particle transport (Vavilov straggling), and correct fission multiplicity.
- True multiprocessing capability via PVM.
- Real detector simulation of He-3 coincidence and radiography.
- "Mix and match" — the capability to use physics models for nuclides and materials where no data tables are available. This is particularly important when modeling burnup where isotopes are produced for which no data libraries exist.

FY03 MCNPX Tasks

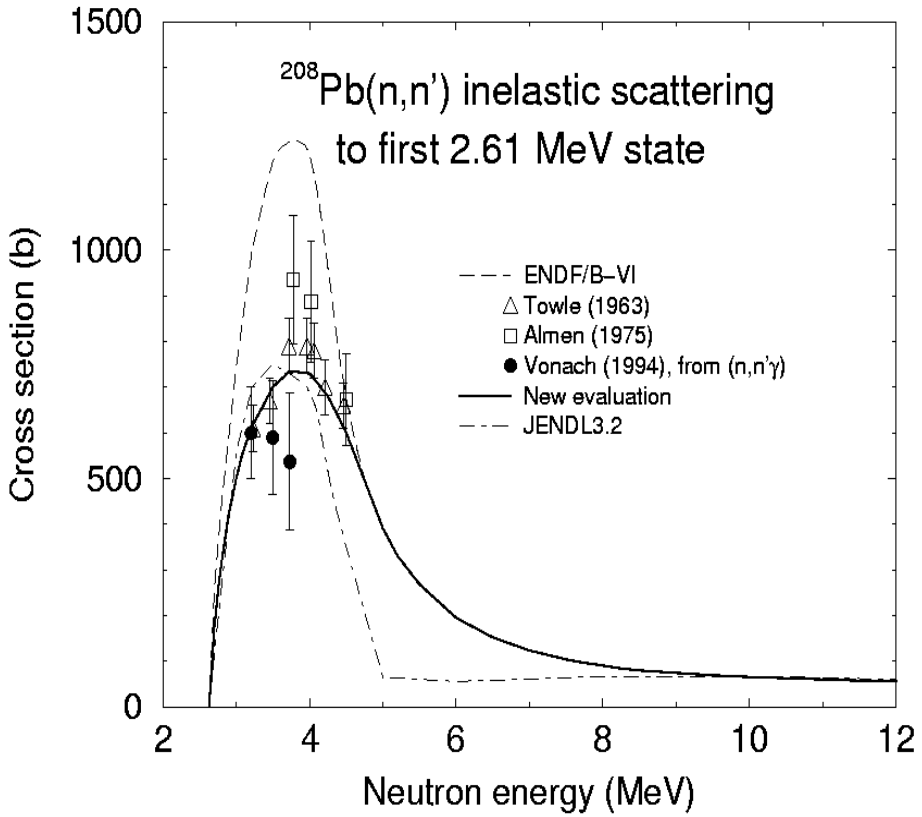
- Incorporation of Cugnon and Schmidt physics models (collaborative effort with CEA-Saclay).
- Extension of variance reduction capabilities to the physics region
  - Forced collisions for neutral particles
  - Weight windows
- Secondary particle angle biasing in the tabular region
- Non-AFCI funded tasks include
  - links to the reactor burnup code Monteburns
  - Conversion of CAD-CAM files to MCNPX geometry files
  - Heavy ion transport

New ENDF LA150 evaluations for actinides (Pu-239, U-238) produced in FY02

- Important in MCNPX for more accurate simulations of criticality, neutron production, damage, and heating.
- Extends our APT "LA150" library for MCNPX. Widely used in the US, Japan, & Europe ADS programs.
- Nuclear reaction theory in GNASH code is used to model (n,xn) and fission. LANSCE/WNR high-energy fission and total cross section data are important for these evaluations.



New Pb-208 ENDF evaluation produced with improved inelastic scattering cross section



- **Deficiencies in previous ENDF data, in the fast energy region, were noted by ANL (Finck et al.), and European & Russian ATW researchers**
- **To produce a new evaluation, nuclear theory was used together with experimental data (including data from LANSCE/WNR – Vonach)**
- **ATW criticality calculations by Embid (Int. Conf. On Partitioning & Transmutation) indicate a ~2.5% effect on k_{eff}.**

New minor actinide evaluations are under development this FY

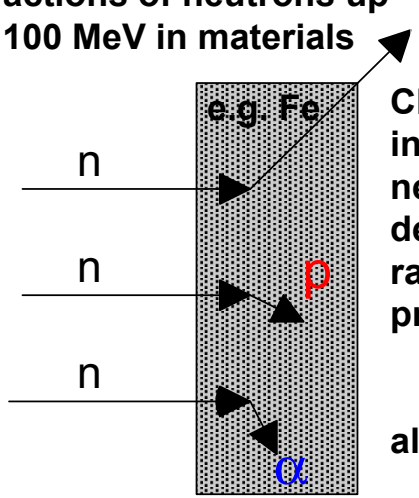
- Cross section evaluations for actinides important in advanced fuel cycles and accelerator-driven systems
  - Np-237 is particularly important based on OECD studies; will improve the inelastic and fission cross sections, and nu-bar.
  - New integral data from the TA-18 criticality experiment (composite Np-U sphere, 6kg Np) will help guide the evaluation.
  - 241Am
- New cross sections for structural materials, for better gas-production (H, He), based on model calculations as well as use of new LANSCE/WNR AFC measurements (Haight)
- Our focus on Np-237 and Am-241 in FY03 is consistent with the conclusions from recent sensitivity uncertainty studies at Argonne National Laboratory

Neutron leakage from thick LBE targets has been measured and compared to code predicitons

- Neutron leakage measured two ways
  - Activation foils
  - Neutron time-of-flight at fixed angles
- Two posters at this review presenting results
- U of Michigan and UNLV participation
- Final report due in March

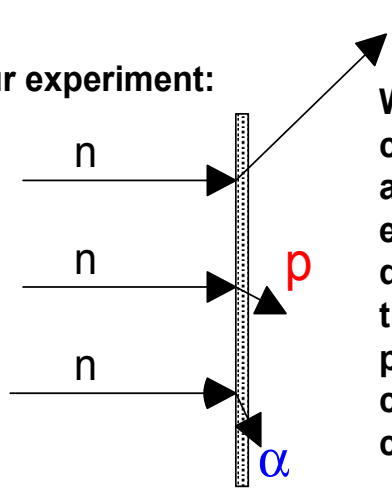
We are measuring gas production (hydrogen and helium) in neutron reactions with structural materials.

Interactions of neutrons up to 100 MeV in materials



Charged particles stop in the material or neighboring materials, depending on the range:
protons -- mm to several cm-> hydrogen
alphas - mm -> helium

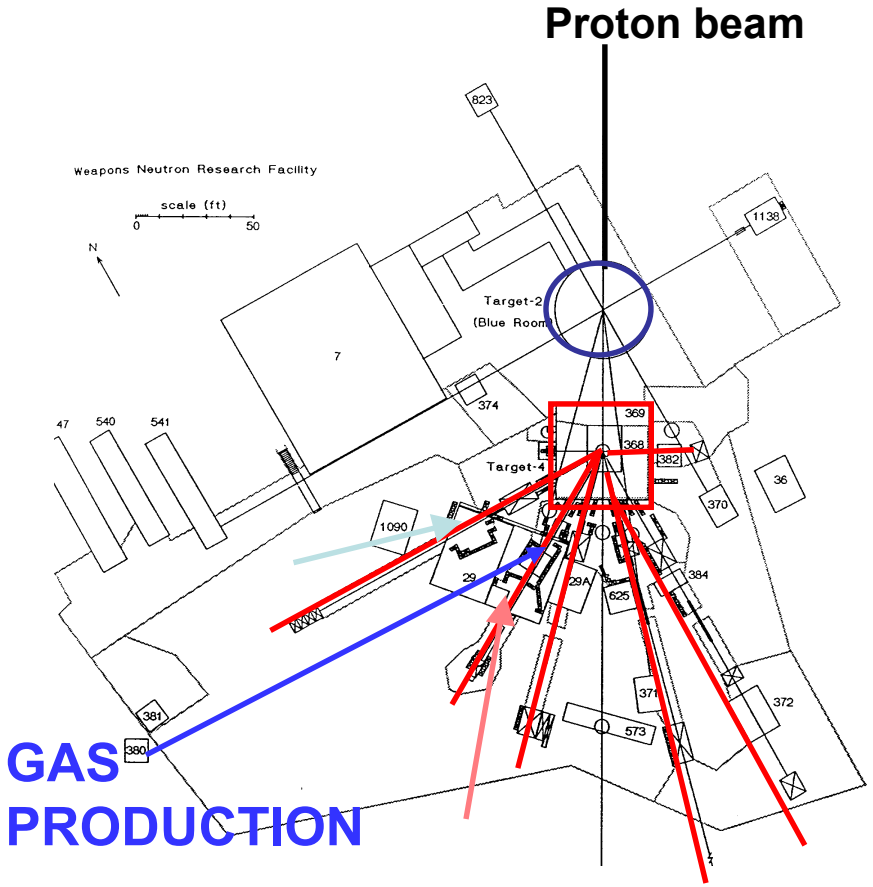
Our experiment:



We detect outgoing charged particles and measure their energy and angular distributions -- then H and He production can be calculated with confidence.

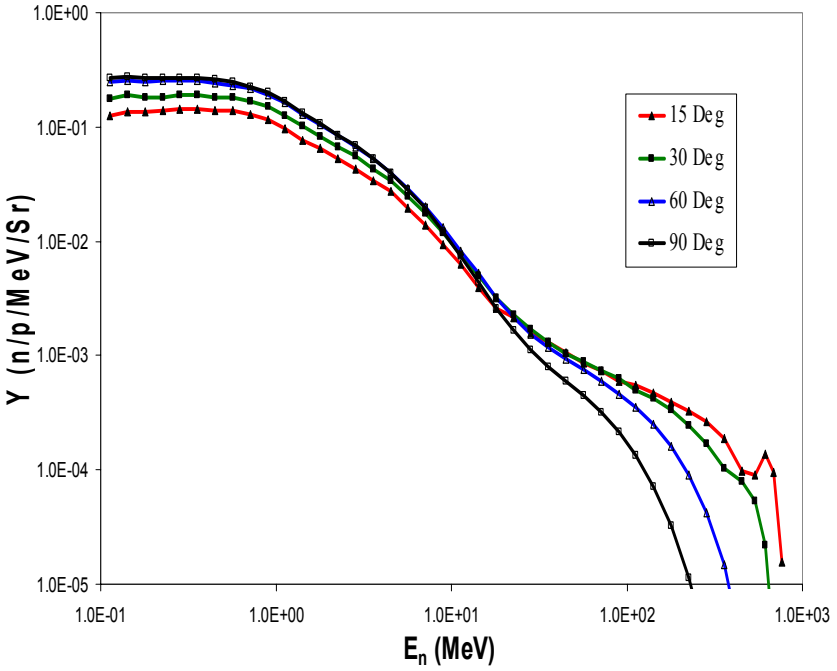
thin foil - to let particles escape with little energy loss

Our neutron source is the spallation neutron source (WNR) at the Los Alamos Neutron Science Center (LANSCE)

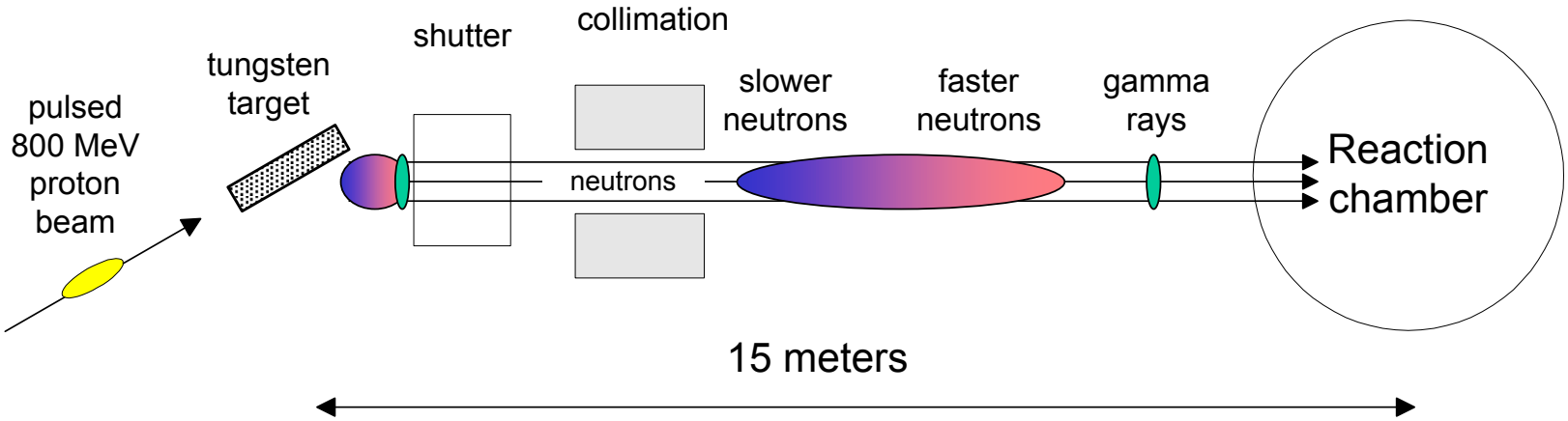


GAS PRODUCTION

Neutron spectrum extends from 1 to ~ 300 MeV

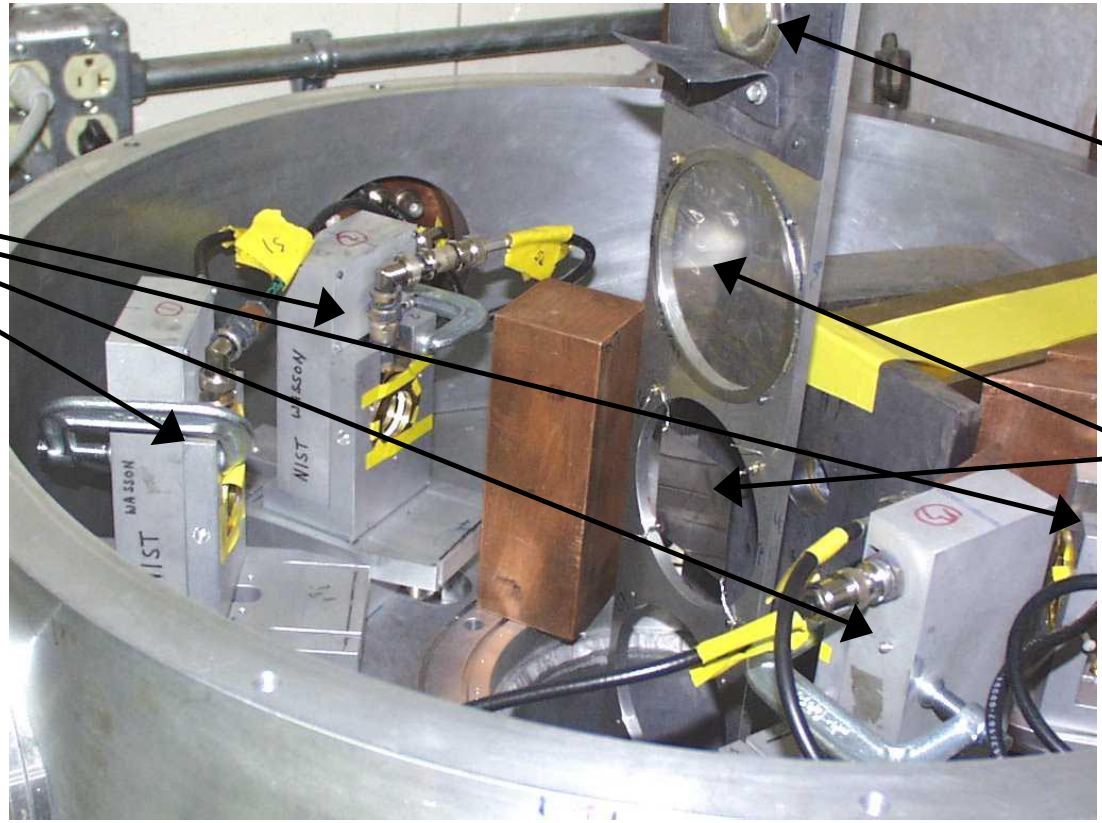


Time of flight over the flight path identifies the energy of the neutron that induces the reaction.



$$E_n \sim v^2 \sim 1/t^2 \quad \text{(nonrelativistic)}$$

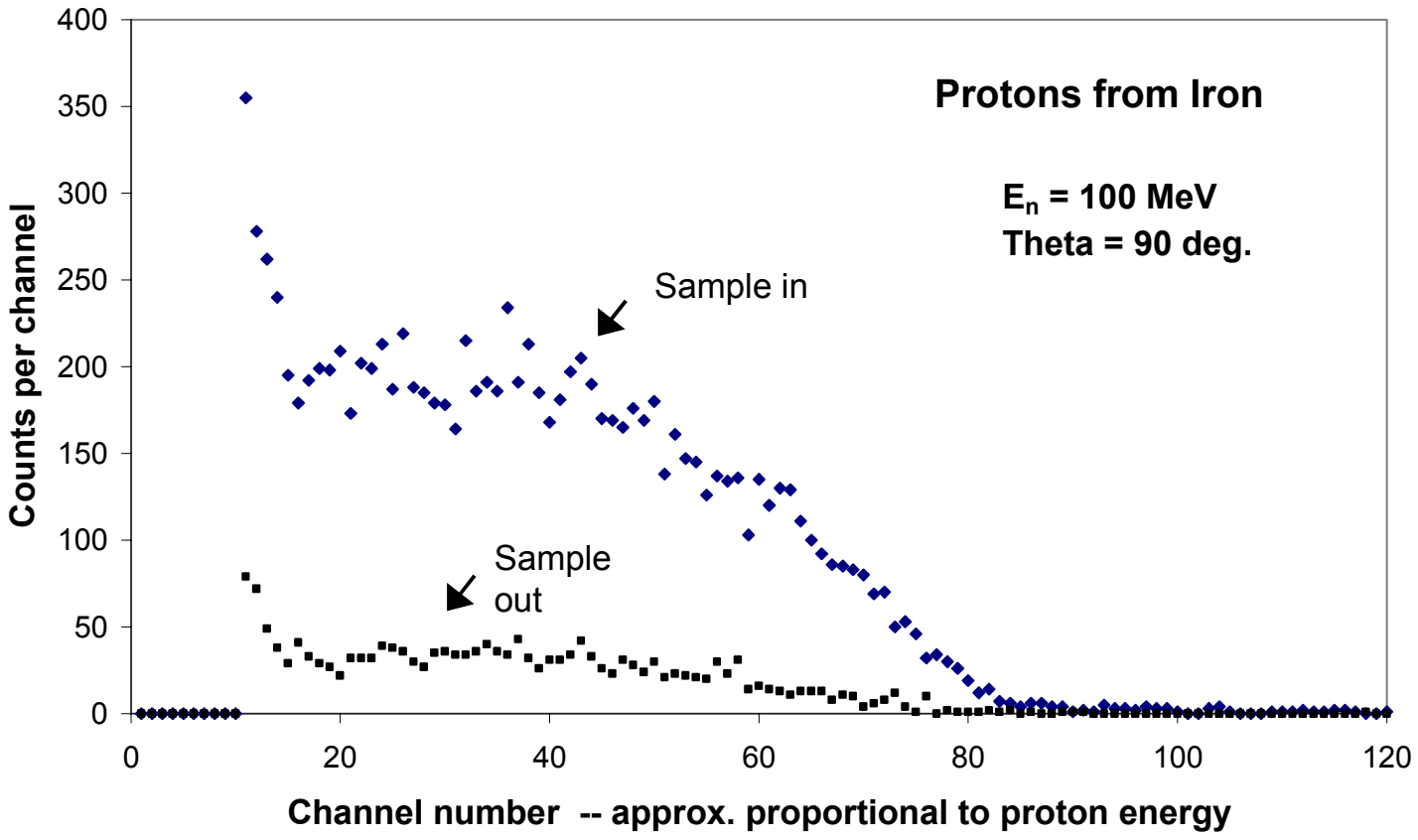
Experimental apparatus consisting of samples and detector telescope are positioned in a reaction chamber.



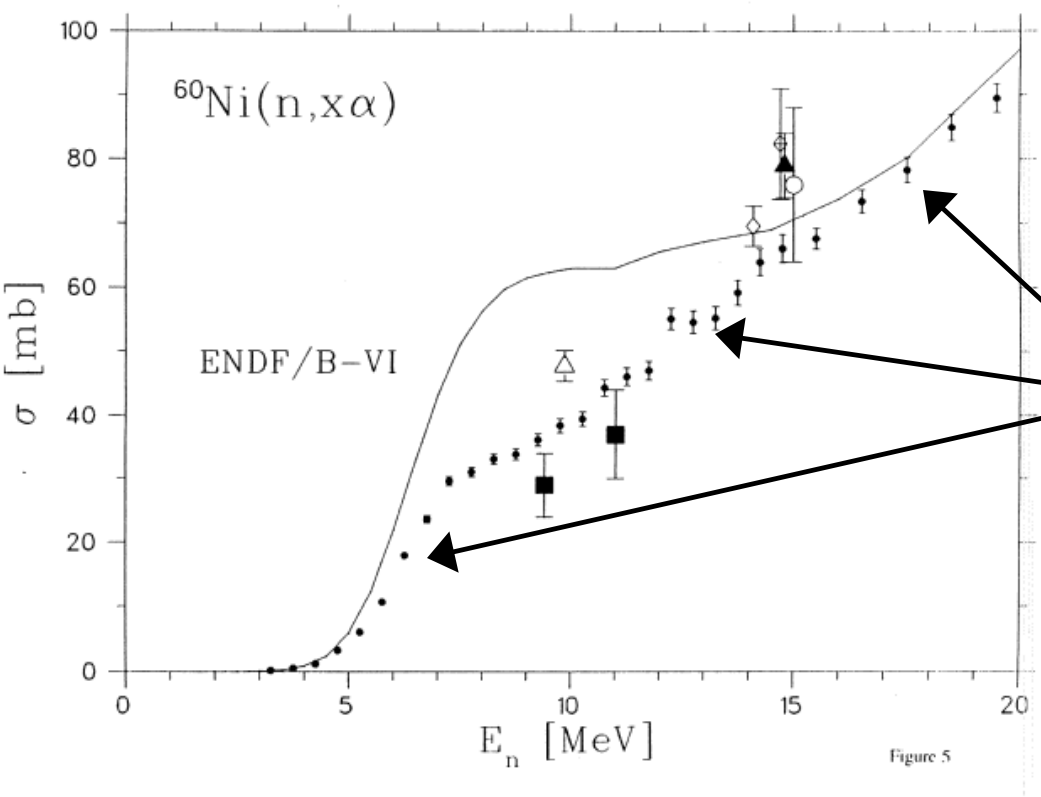
Progress to date (January, 2003)

- Commissioning completed
- Data taking continued through December 24, 2002
- Samples investigated:
  - Iron (thick and thin)
  - 58Ni(very thin) – might need more statistics
  - 60Ni(very thin) – will need more statistics
- Data analysis started

Preliminary analysis shows good signal-to-noise ratio at E = 100 MeV, better still at lower energies



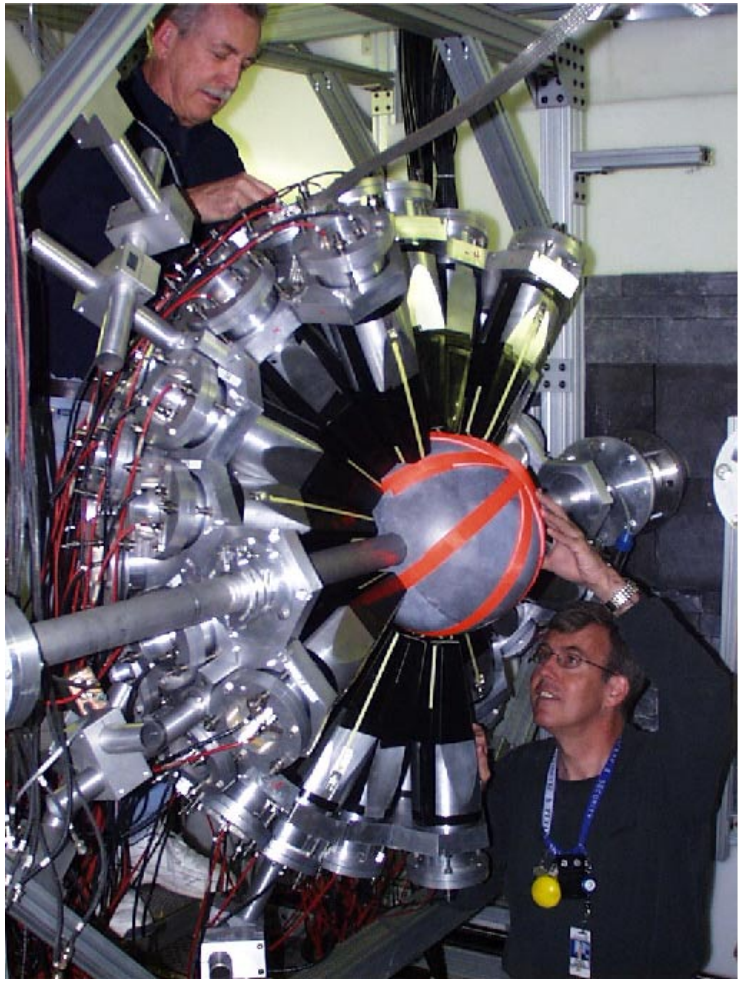
Final data will look like these data for the spectrum-integrated cross sections for ^{60}Ni…



Previous LANSCE data

... except they will extend to E_n = 100 MeV

New DANCE instrument will be used to measure Np-237 capture cross section this summer



- Specifically designed for measuring the capture cross section of radioactive nuclides
- 4π barium flouride detector located on a 20-m flight path at the Lujan Center
- Energy range 1 eV to 100 keV
- 1 mg sample size
- 2 ns resolution in neutron time-of-flight
- Proposal for measuring Np-237 to be submitted to the Program Advisory Committee next month

Fission cross section measurements

- **Evaluation underway to determine the best beam line for making fission cross section measurements**
  - **Flight path on Target 4 for high energies**
  - **Flight path 5 at Lujan Center for low energies**
  - **Can DANCE be used?**

Measurements of minor actinide temperature coefficients are being planned

- Use one or more critical assemblies at the Los Alamos Critical Effects Facility (TA-18)
- Measurement sensitivity in $\Delta k/k \sim 10^{-5}$, possibly lower
- Use encapsulated samples of actinides that can be heated to high temperature (~600 K)
- Work to start shortly to estimate the quantity of minor actinide material needed to make a meaningful measurement